

# What controls the monthly variability of the lunar Na exosphere?

Menelaos Sarantos

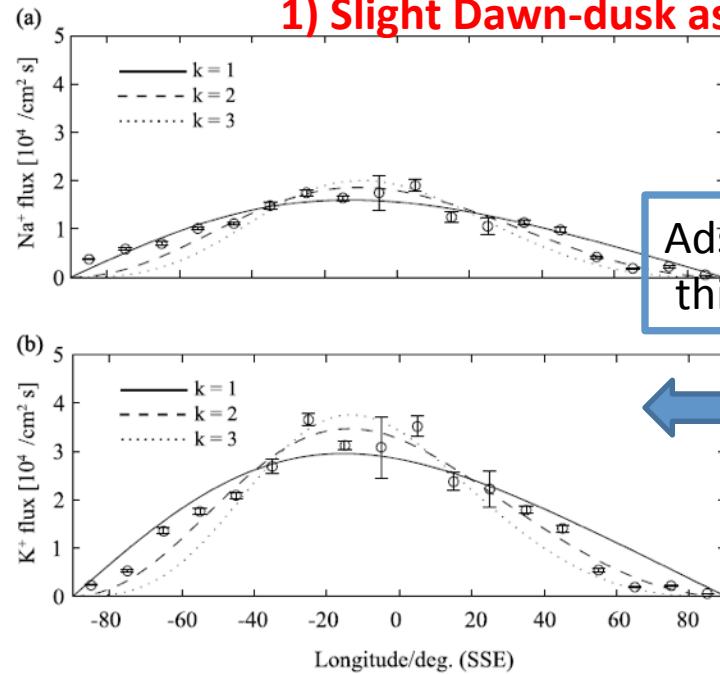
Anthony Colaprete, Rosemary Killen, Andrew Poppe



Formerly the NASA LUNAR SCIENCE INSTITUTE

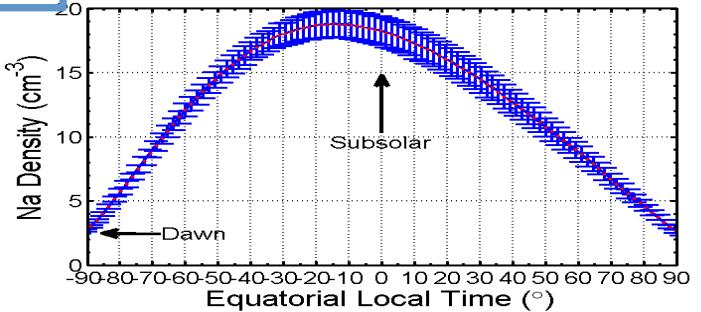
# Kaguya surprises!

**1) Slight Dawn-dusk asymmetry** Yokota et al. JGR, 2014

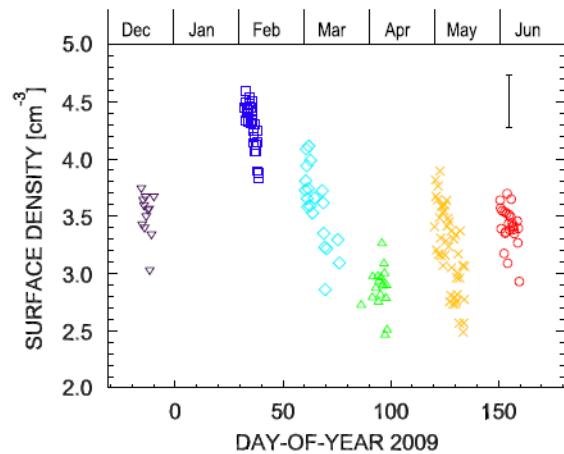


Adsorbates explain  
this finding

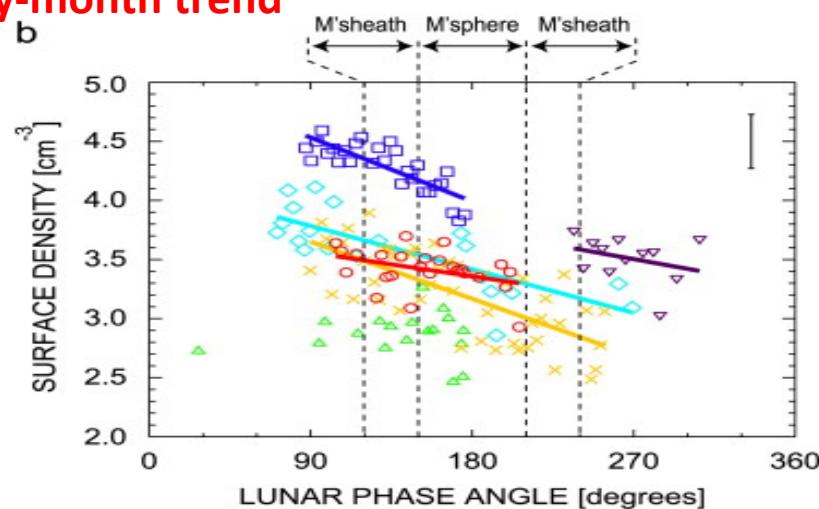
Na/K migrate like volatiles  
(e.g., water)



**2) Monthly and month-by-month trend**



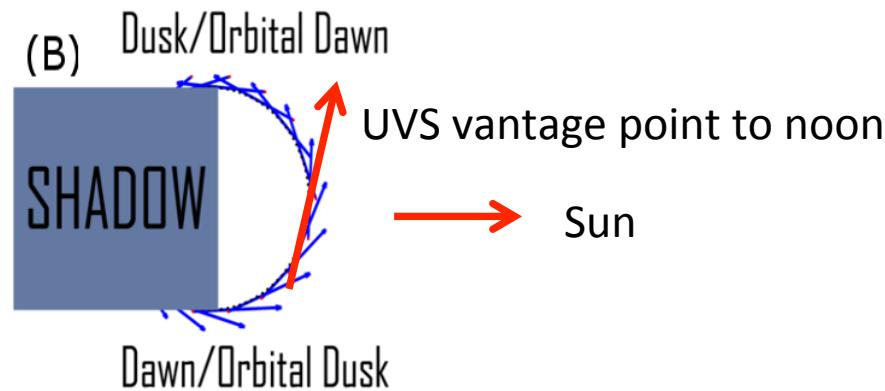
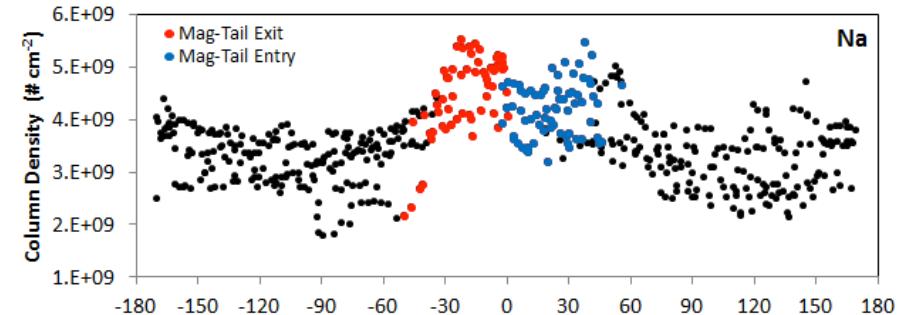
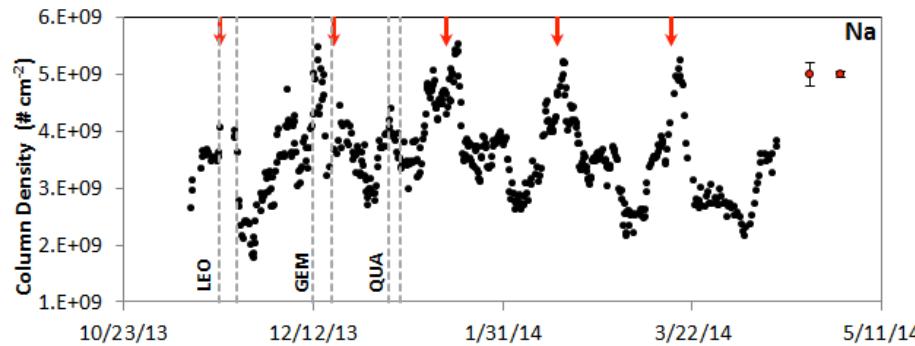
Kagitani et al. , 2010



???

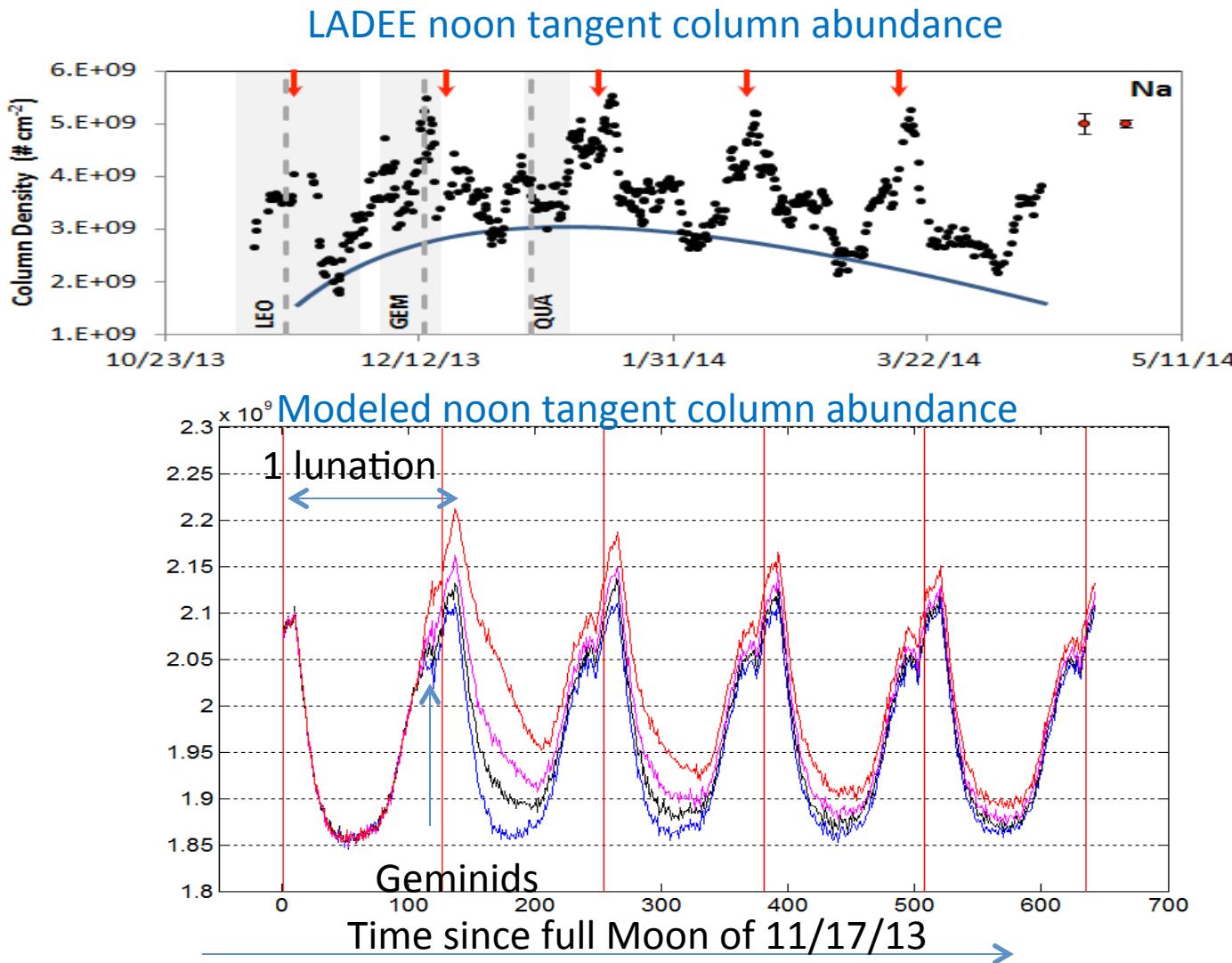
# LADEE data brought new questions!

Colaprete et al., in preparation



- What are the causes of periodicity observed by UVS?

# An atmosphere in continuous change!

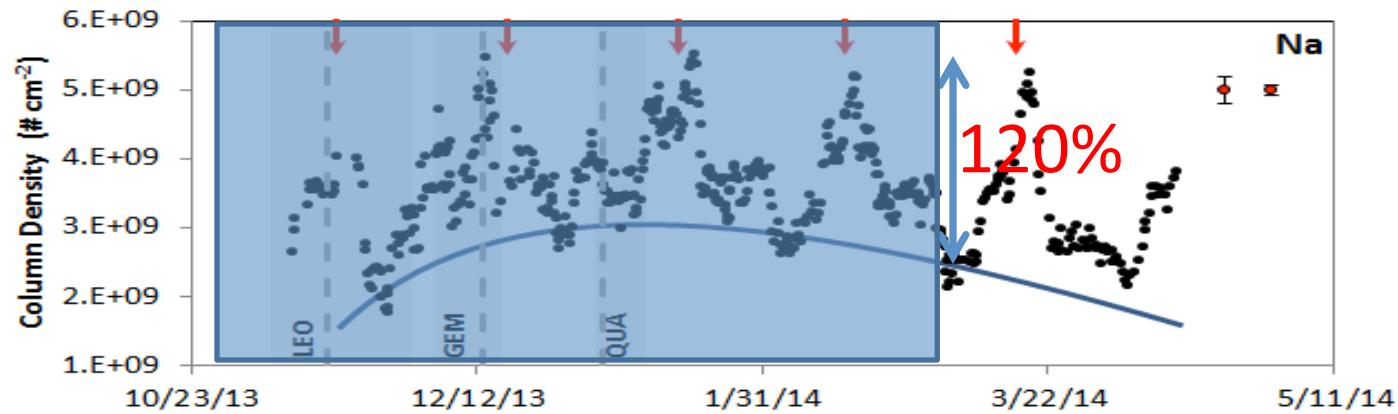


Different cases were modeled:

Blue=constant impact vaporization;  
Magenta==x2 during Geminids  
Red=x3 during Geminids

Conclusion: we only see the Na atmosphere in steady state during the last LADEE lunation.

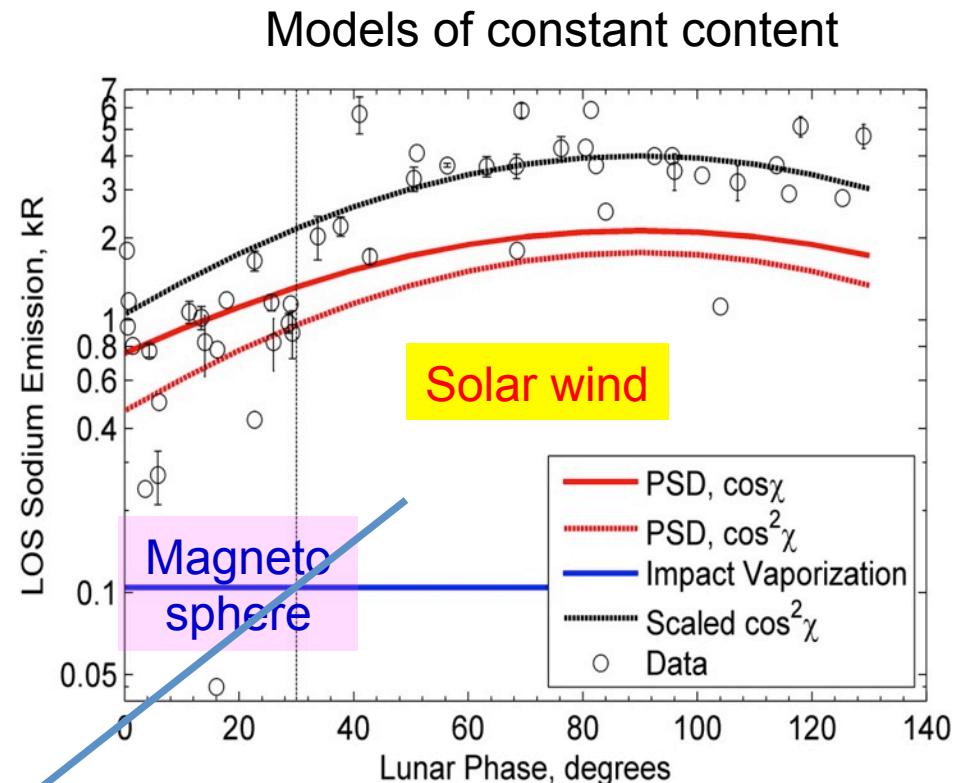
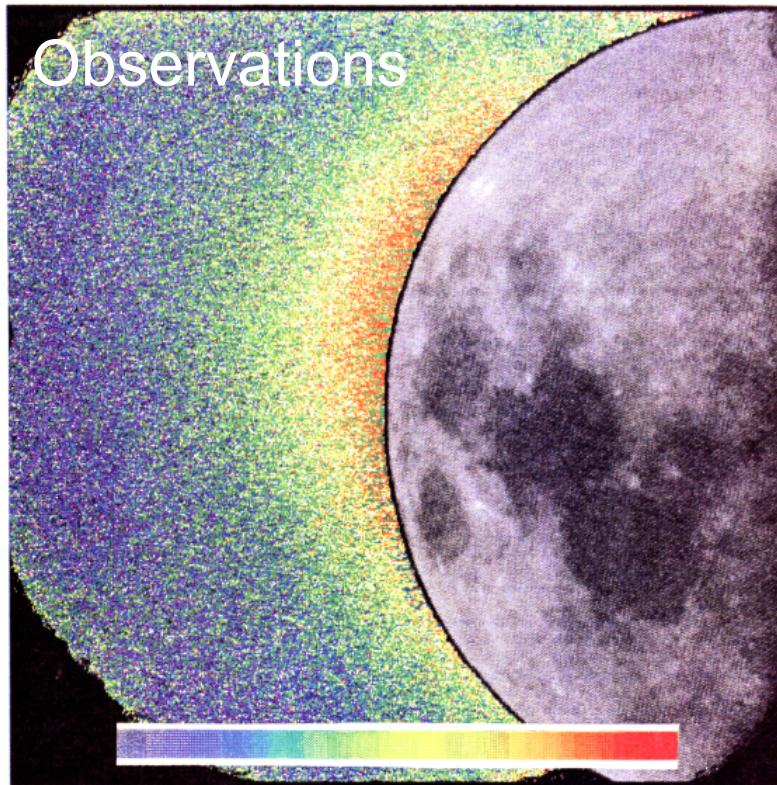
Problem: variation by more than x2 in a month is hard to explain!



Topic of this talk: what does this monthly variation tell us?

# Old theory: solar wind source responsible for factor of two variation in one lunation

Potter and Morgan, 1998

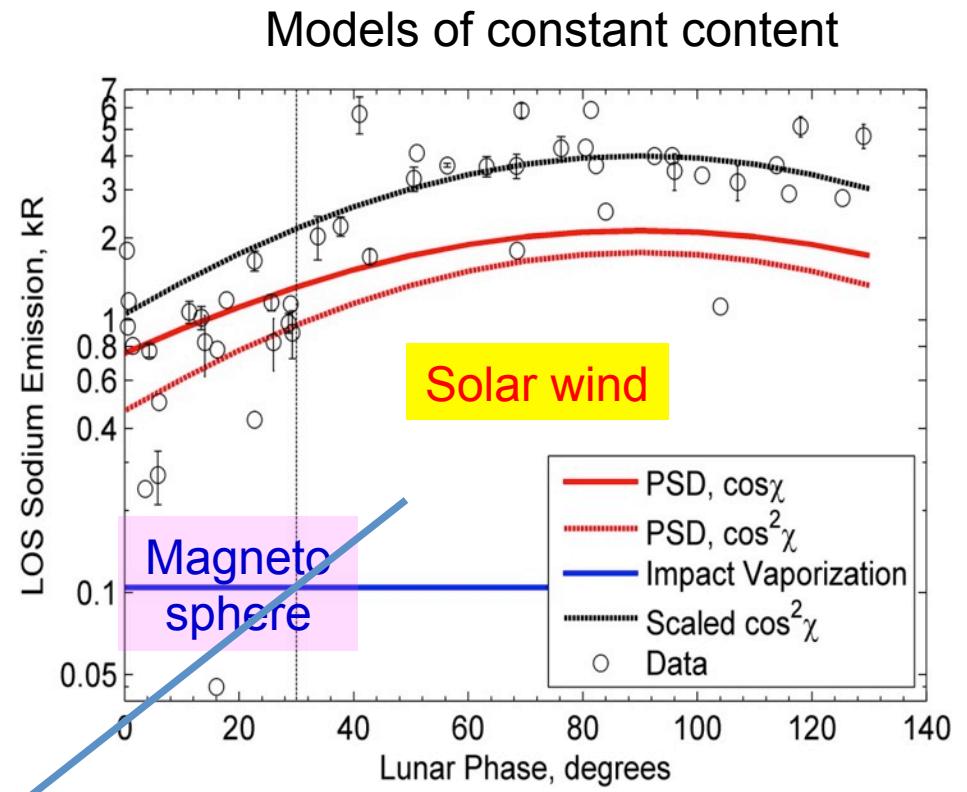
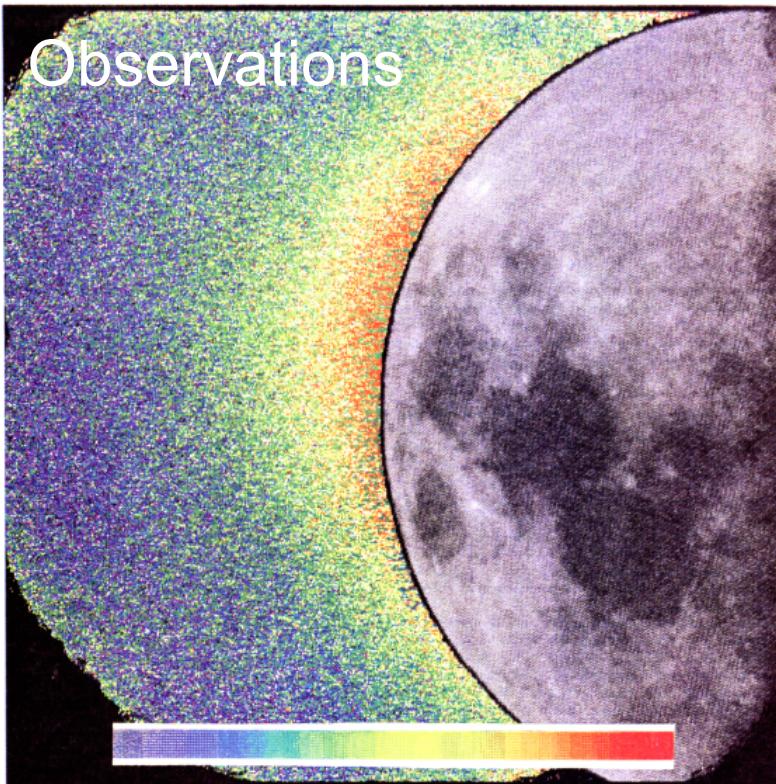


Sarantos et al., 2010

Factor of two discrepancy between data at full and Quarter Moon → solar wind enhancing  
The efficiency of PSD through diffusive processes?

# ~~Old theory: solar wind source responsible for factor of two variation in one lunation~~

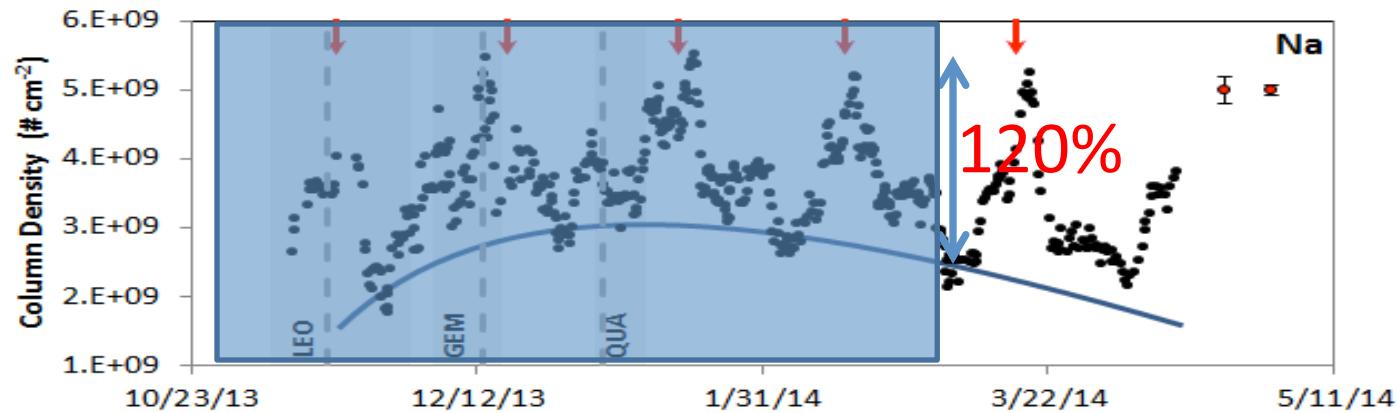
Potter and Morgan, 1998



Sarantos et al., 2010

Factor of two discrepancy between data at full and Quarter Moon → solar wind enhancing  
The efficiency of PSD through diffusive processes?

# New conceptual picture emerges from Kaguya and LADEE data



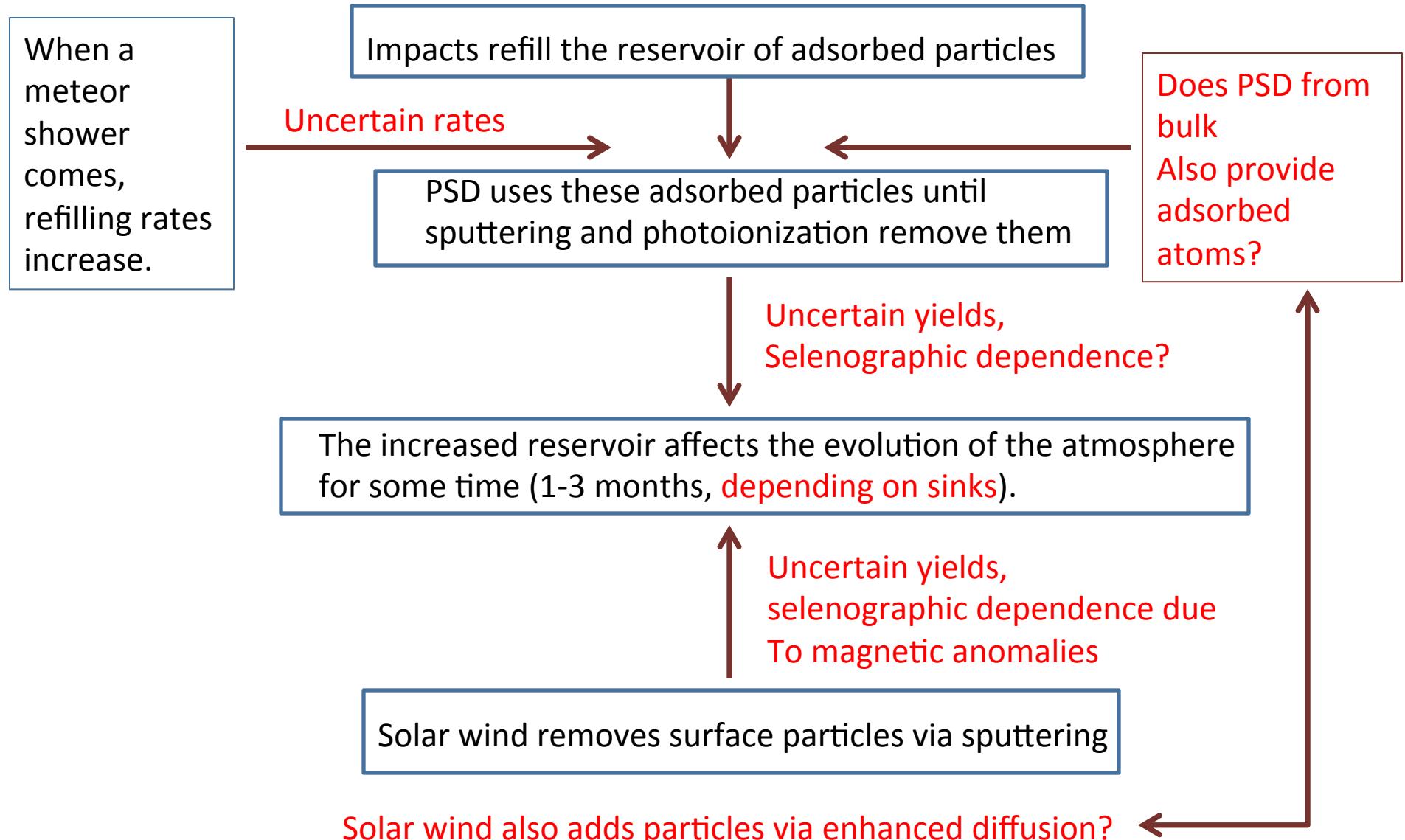
Options:

1. Constant source rate but variable sinks in a month?
2. Rapidly varying source rates in a month?
3. Selenographic dependence of parameters for gas-soil interaction?

And combinations thereof.

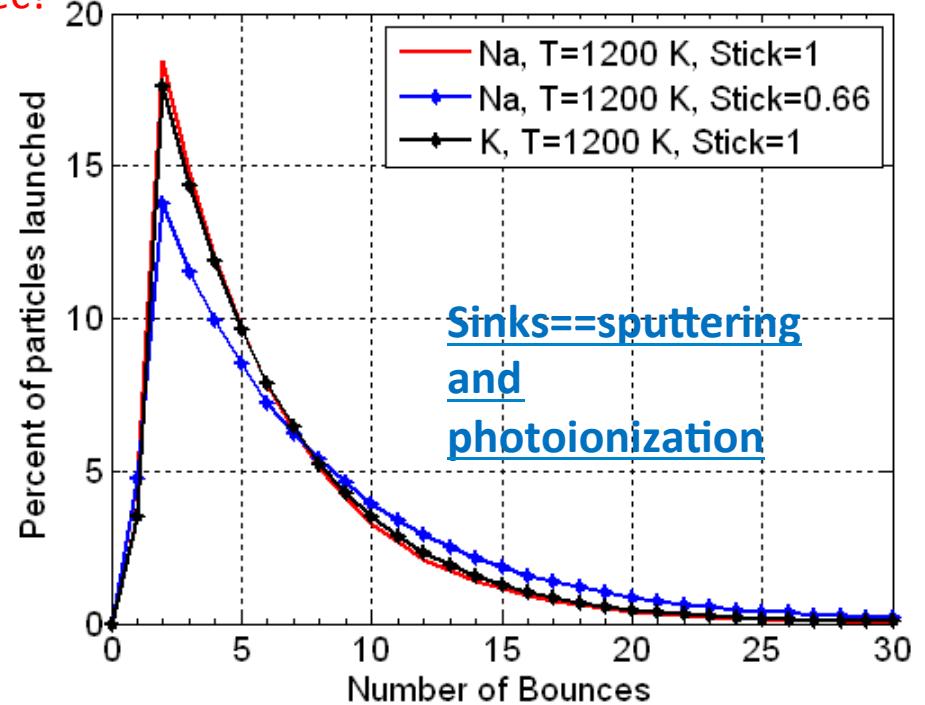
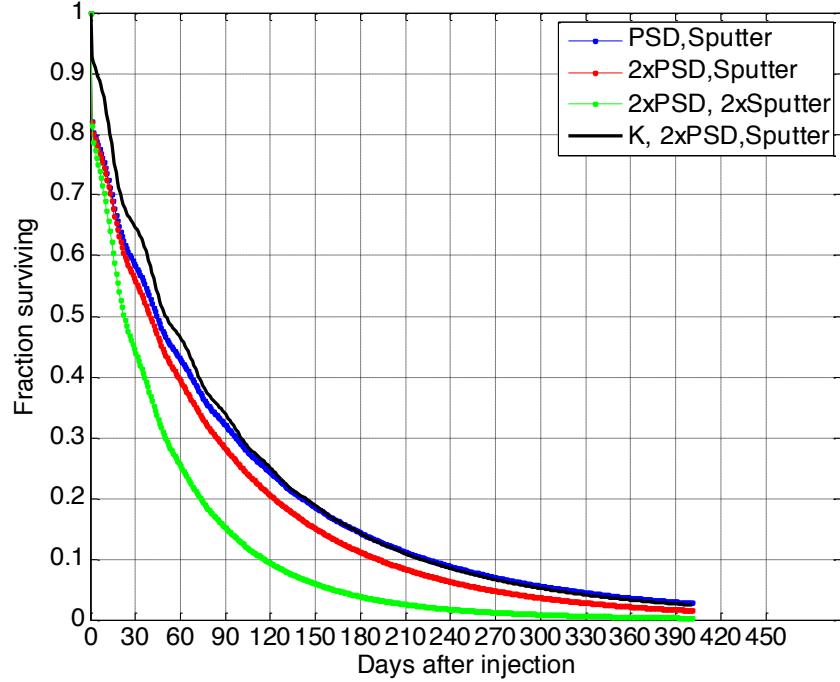
# **Causal models of lunar Na: supply and loss for the exosphere and soil**

# Chain of events in/on the lunar soil ?



# Na adsorbates affect exosphere on later lunations!

Let's release a jet from the dayside for one sec!



Combine Between-bounce Residence time of adsorbed particles @ subsolar ~ 5 days

@ 60deg lat ~ 12 days

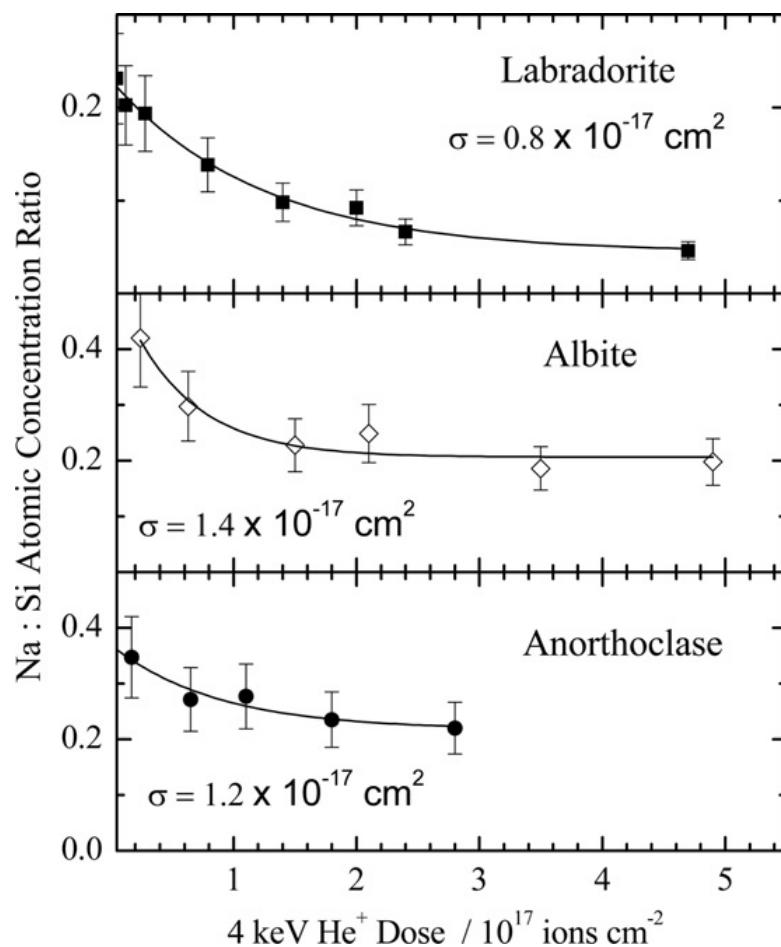
@ 70deg lat ~ 35 days

And the mean number of bounces before elimination from surface-exosphere system

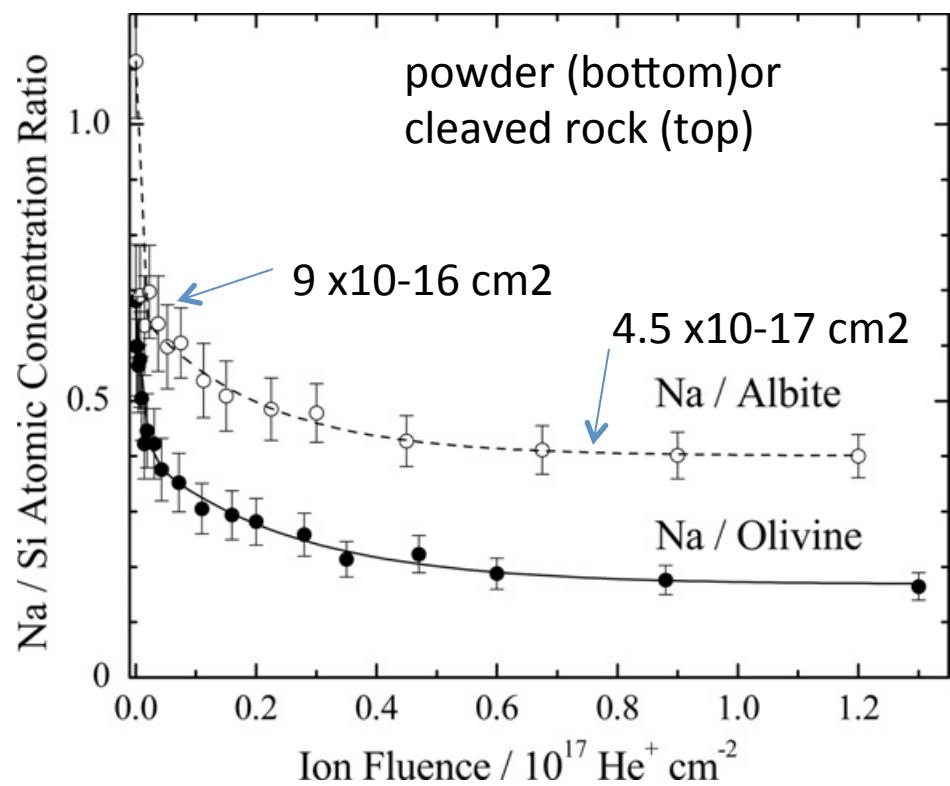
Hypothesis #1:  
Constant source rate but variable  
escape rate with lunar phase?

# Sputtering from adsorbates is x20 easier!

Sputtering of intrinsic sodium (powder)



Sputtering of sodium coated onto mineral

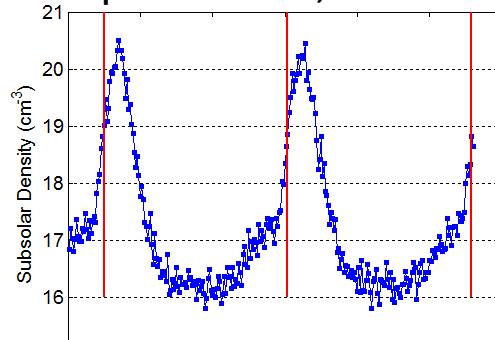


Figures from Dukes et al., 2011

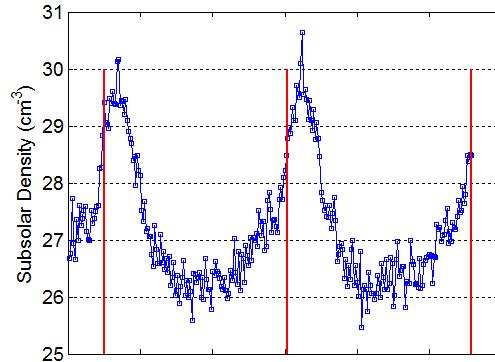
- TRIM calculations for 4 keV He<sup>+</sup> on stoichiometric albite suggest a sputtering yield 5 larger than for 1 keV protons (Ziegler, 2008).

High sputtering of adsorbates → higher amplitude of monthly variation

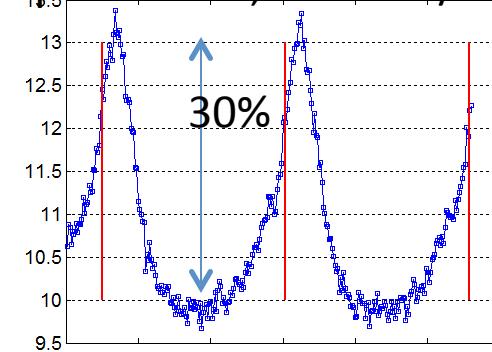
$2^* \text{SputterYield, PSDRate}/2$



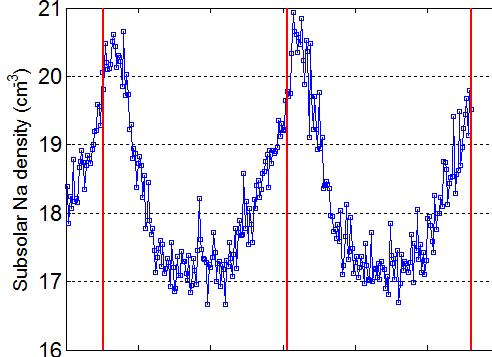
$\text{SputterYield, PSDRate}/2$



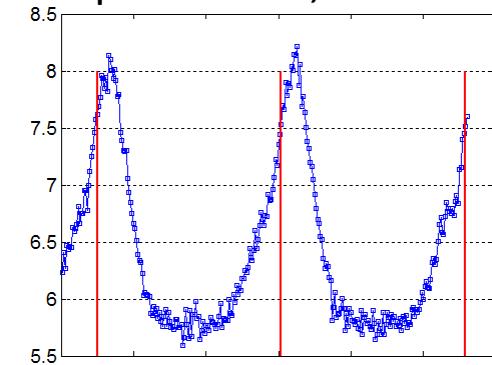
$2^*\text{SputterYield, PSDRate}/4$



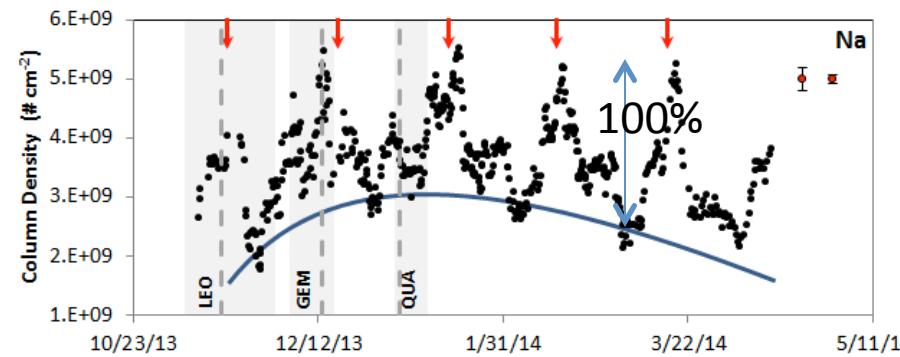
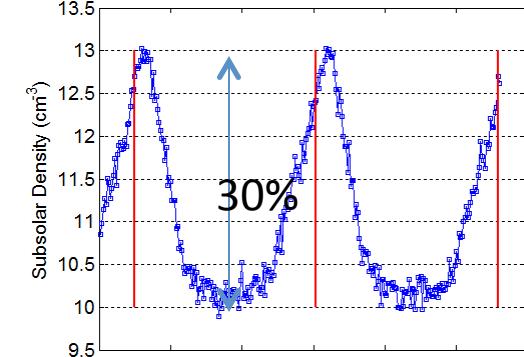
$\text{SputterYield, PSDRate}/4$



$2^*\text{SputterYield, PSDRate}/8$



$\text{SputterYield, PSDRate}/8$

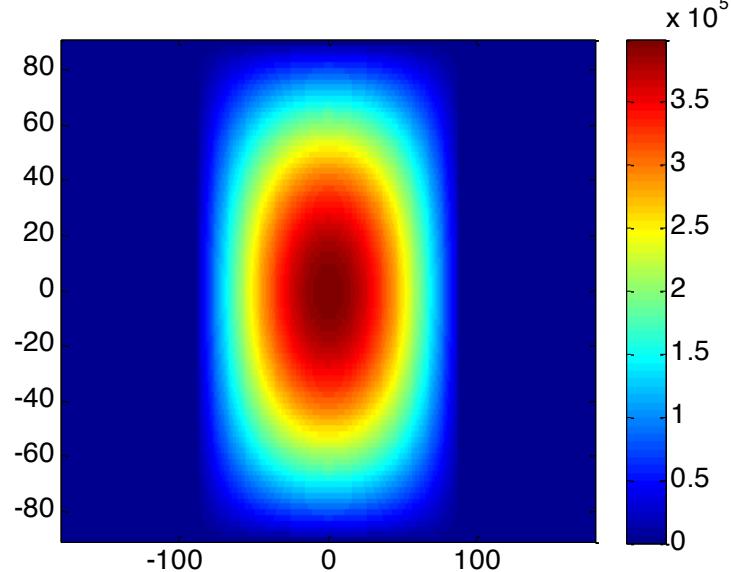


...but no reasonable amount of sputtering can produce the magnitude of observed variation in one month

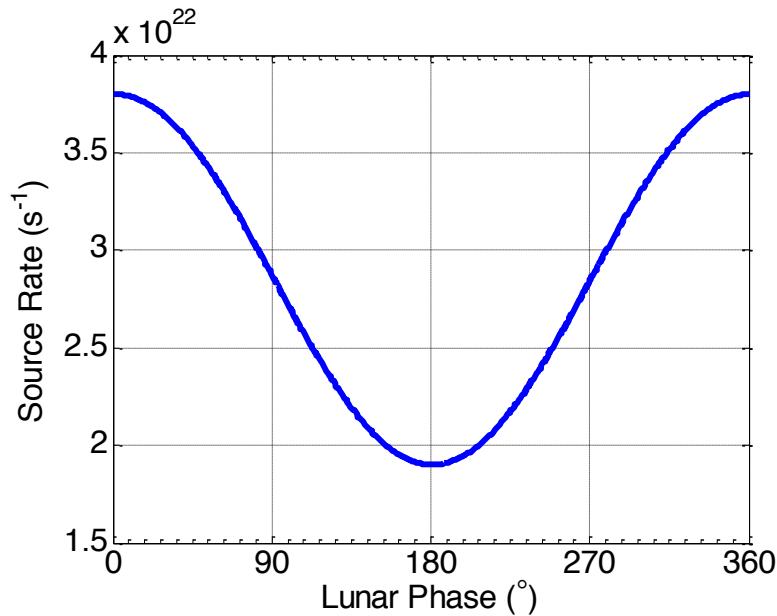
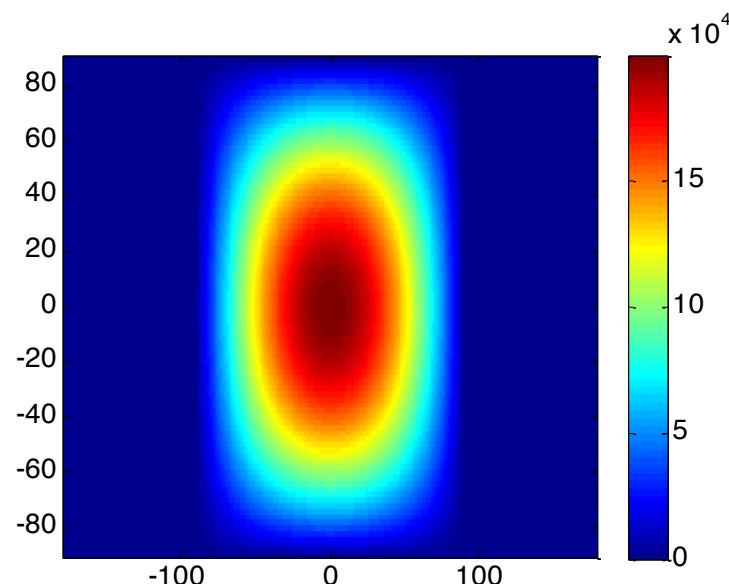
Hypothesis #2:  
High source rate on the nearside?

# Case study 1: Nearsidex2 PSD source

Assumed Efflux (/cm<sup>2</sup> s) at Full Moon

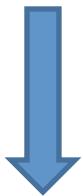
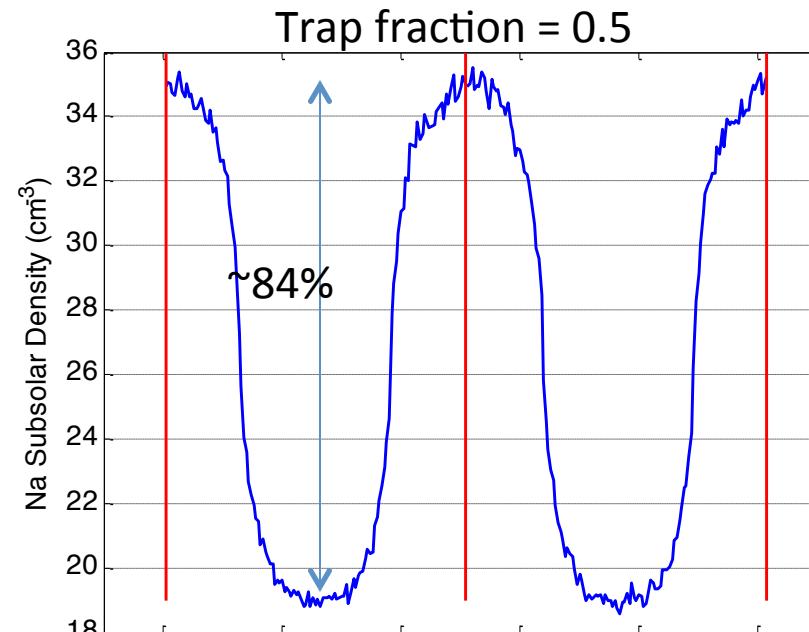
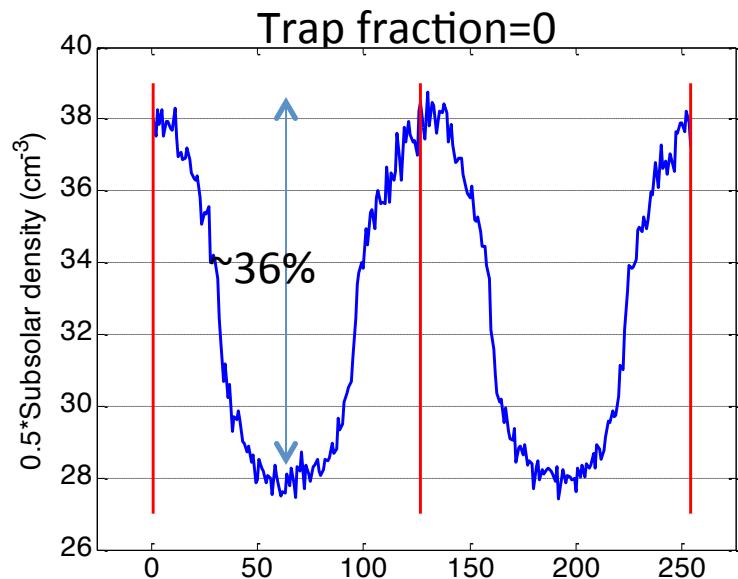


Assumed Efflux (/cm<sup>2</sup> s) at Full Moon



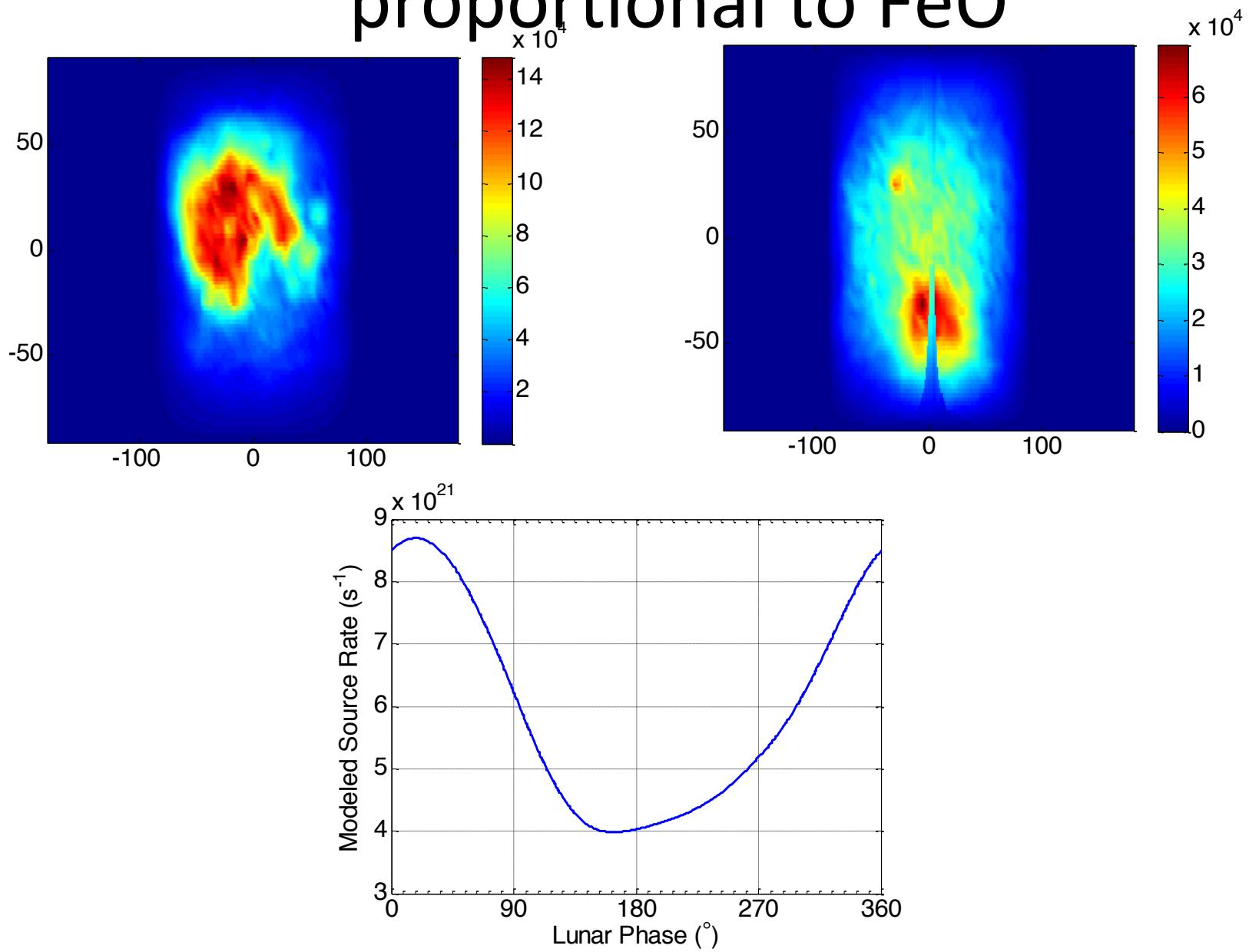
- No impact vaporization refilling

The more you re-use these particles, the more you diffuse the source rate variation

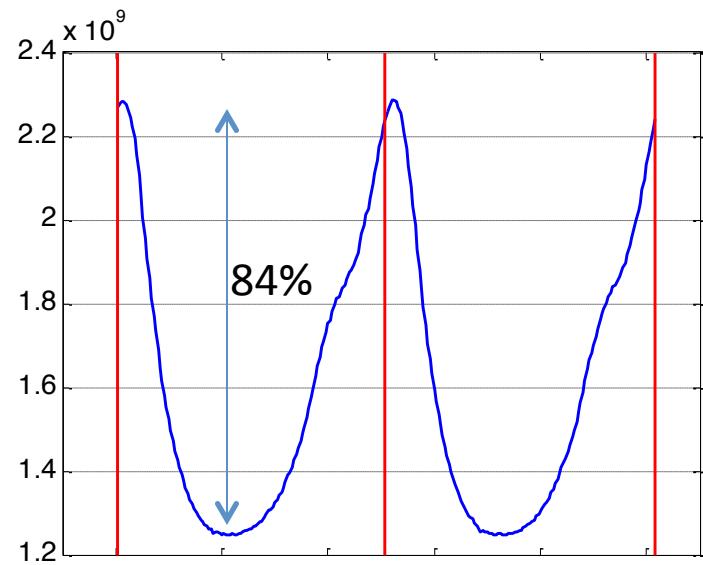


To produce  $x2$  under assumption of adsorbed component, you need high rates on nearside!

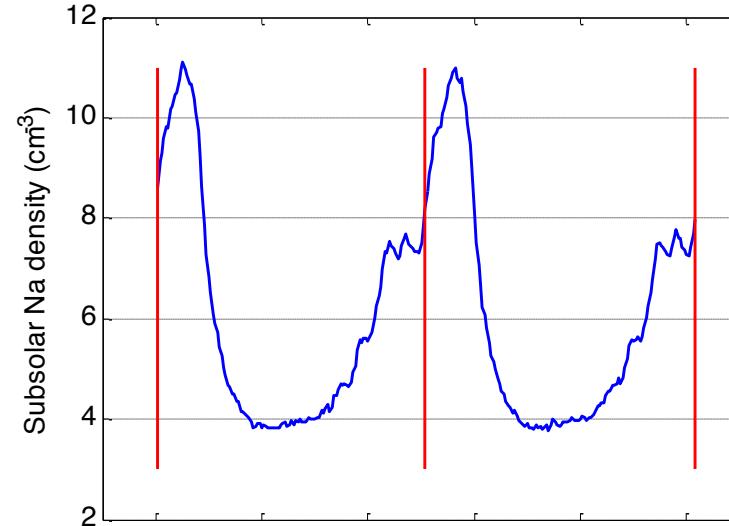
# Hypothetical Scenario 2: PSD source proportional to FeO



# Case: PSD source proportional to FeO

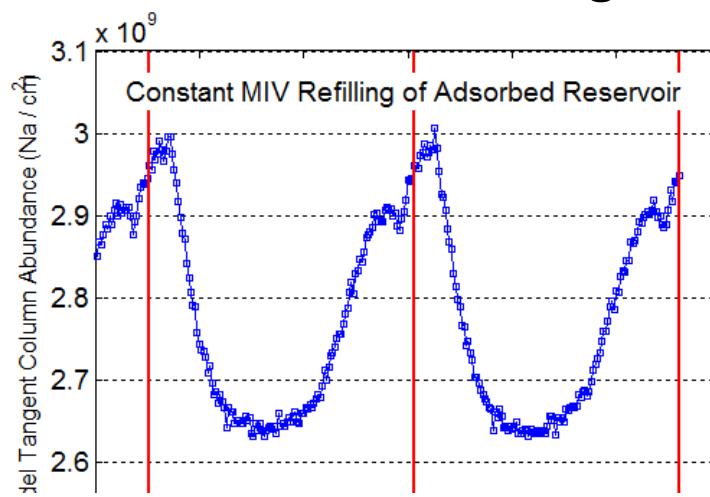


Trap=0



Trap=0.5

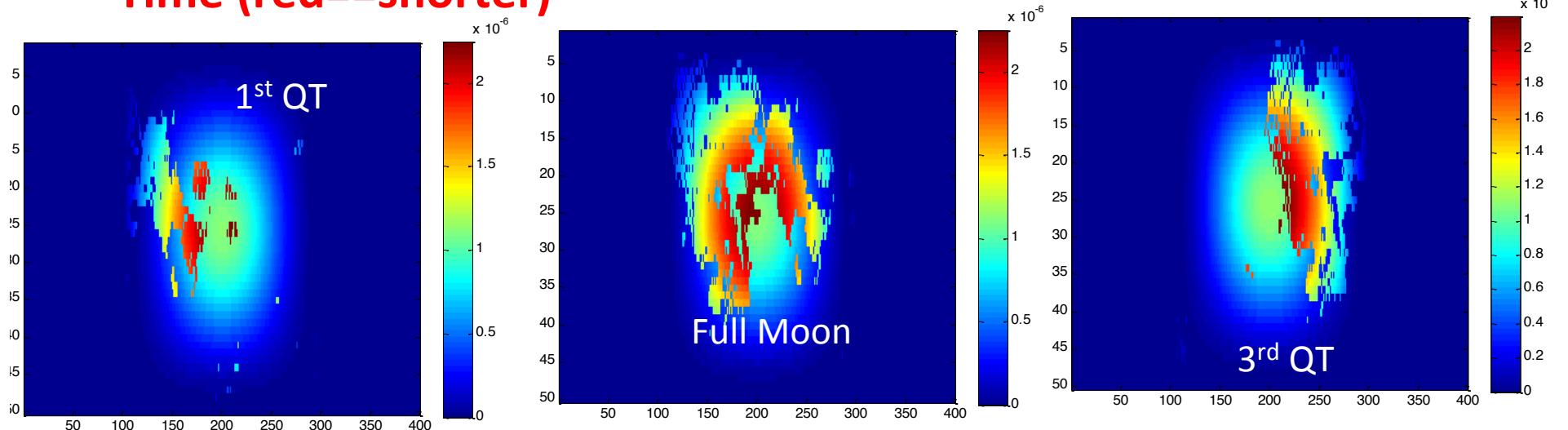
Reference case constant rate with high adsorbate sputtering



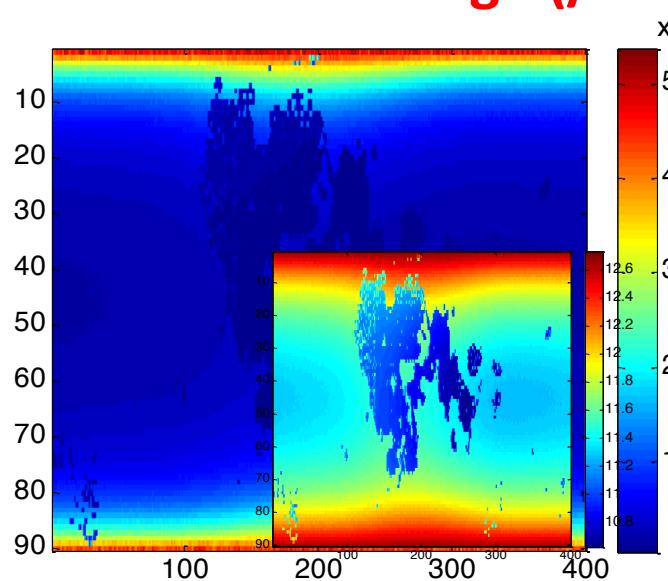
Hypothesis #3:  
Selenographic dependence of gas-  
soil parameters?

# Assume PSD rate is highest on Mare soils

Residence time on surface due to PSD Na as a function of Local Time (red==shorter)

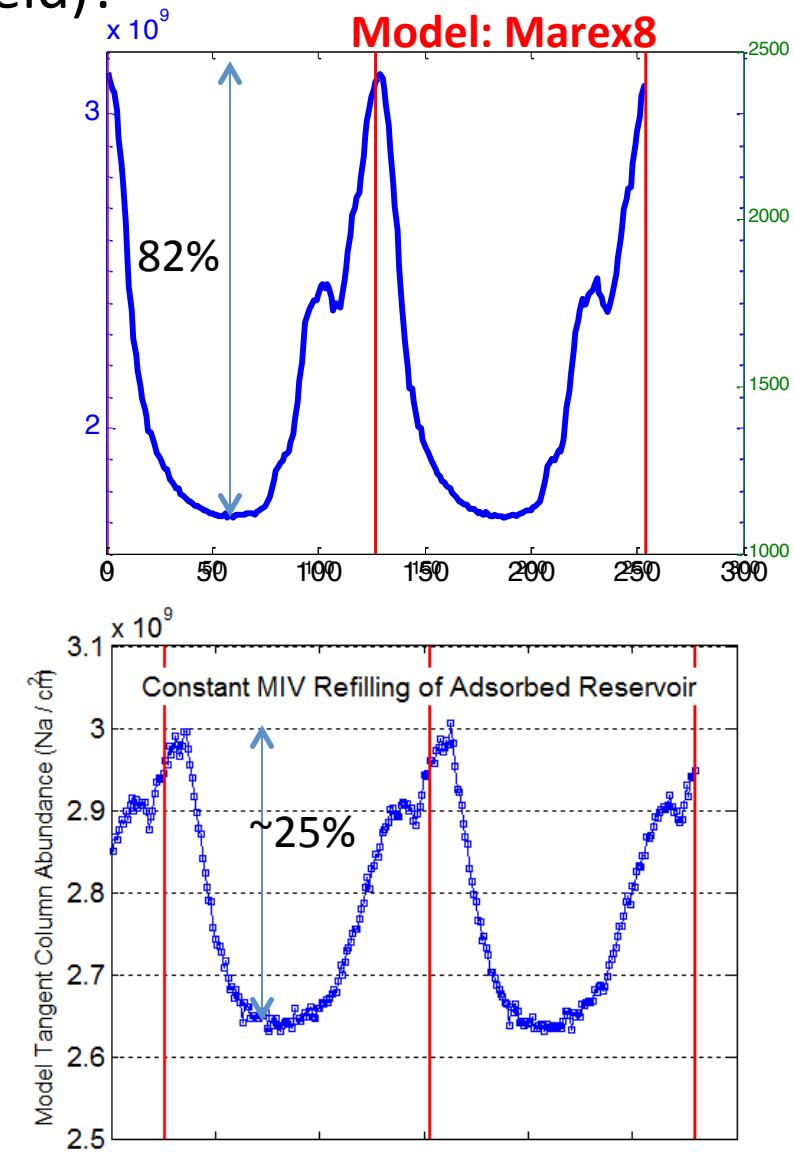
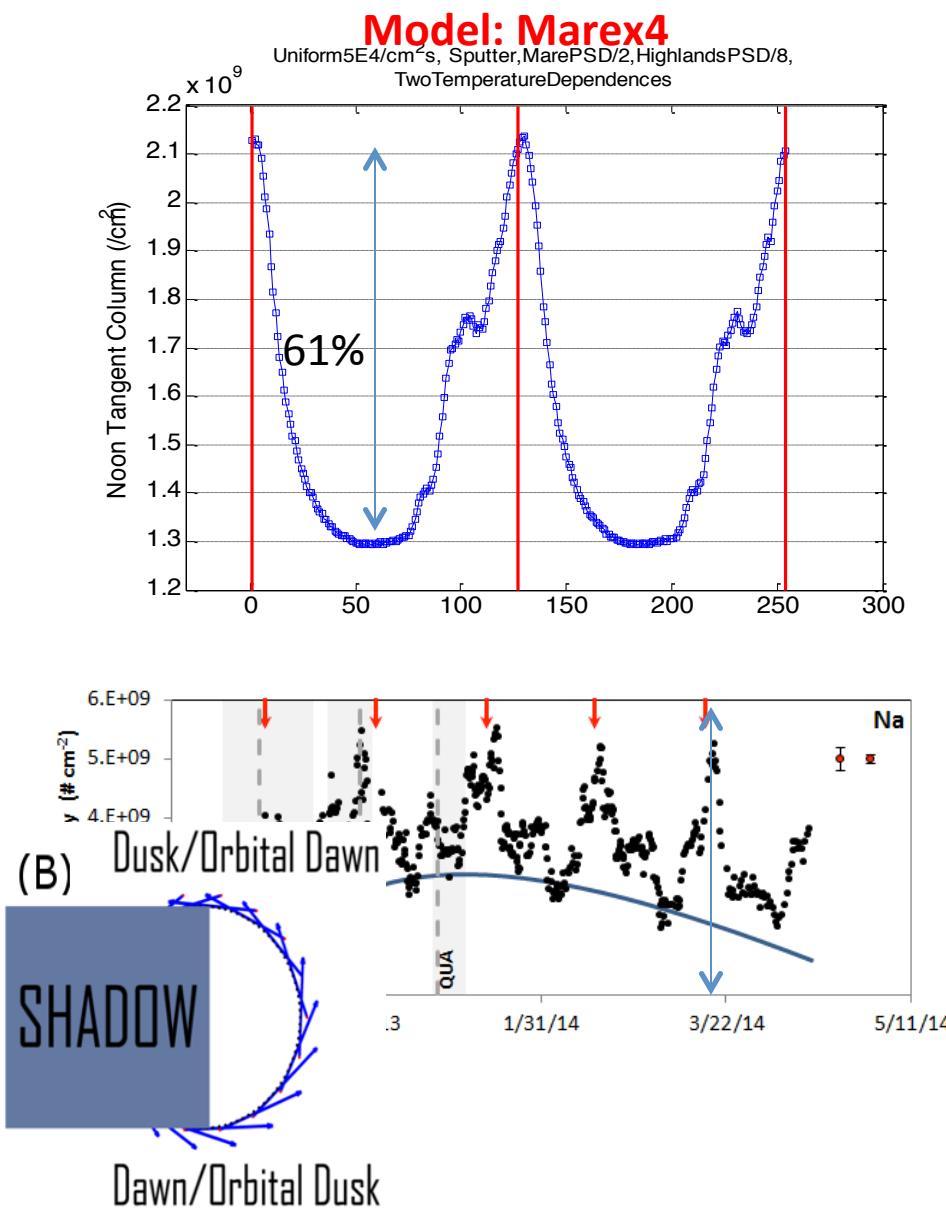


Resulting Na surface coverage (/cm<sup>2</sup>) at Full Moon



This model:  
Get particles off the ground  
Quicker on nearside Mare soils

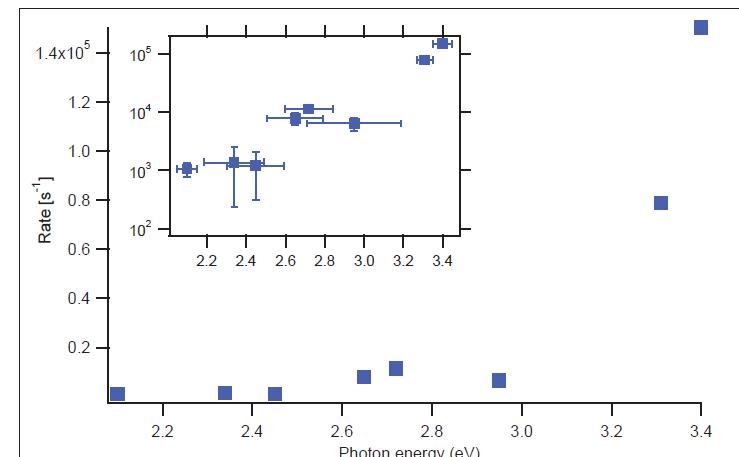
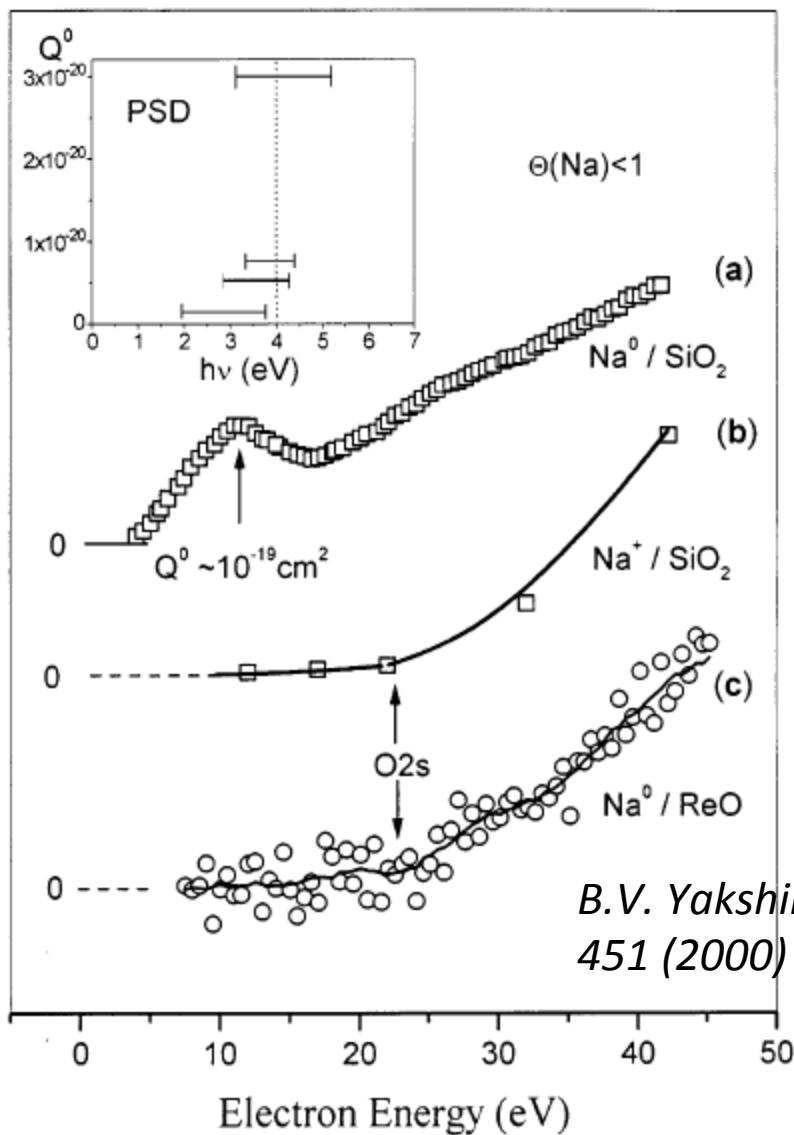
Hypothesis: what if Mare soils have shorter residence time (i.e., higher PSD yield)?



# Interpretation

Desorption by illumination varies a lot for Na/different oxides and glasses...and should vary for different lunar soils!

### ESD Thresholds



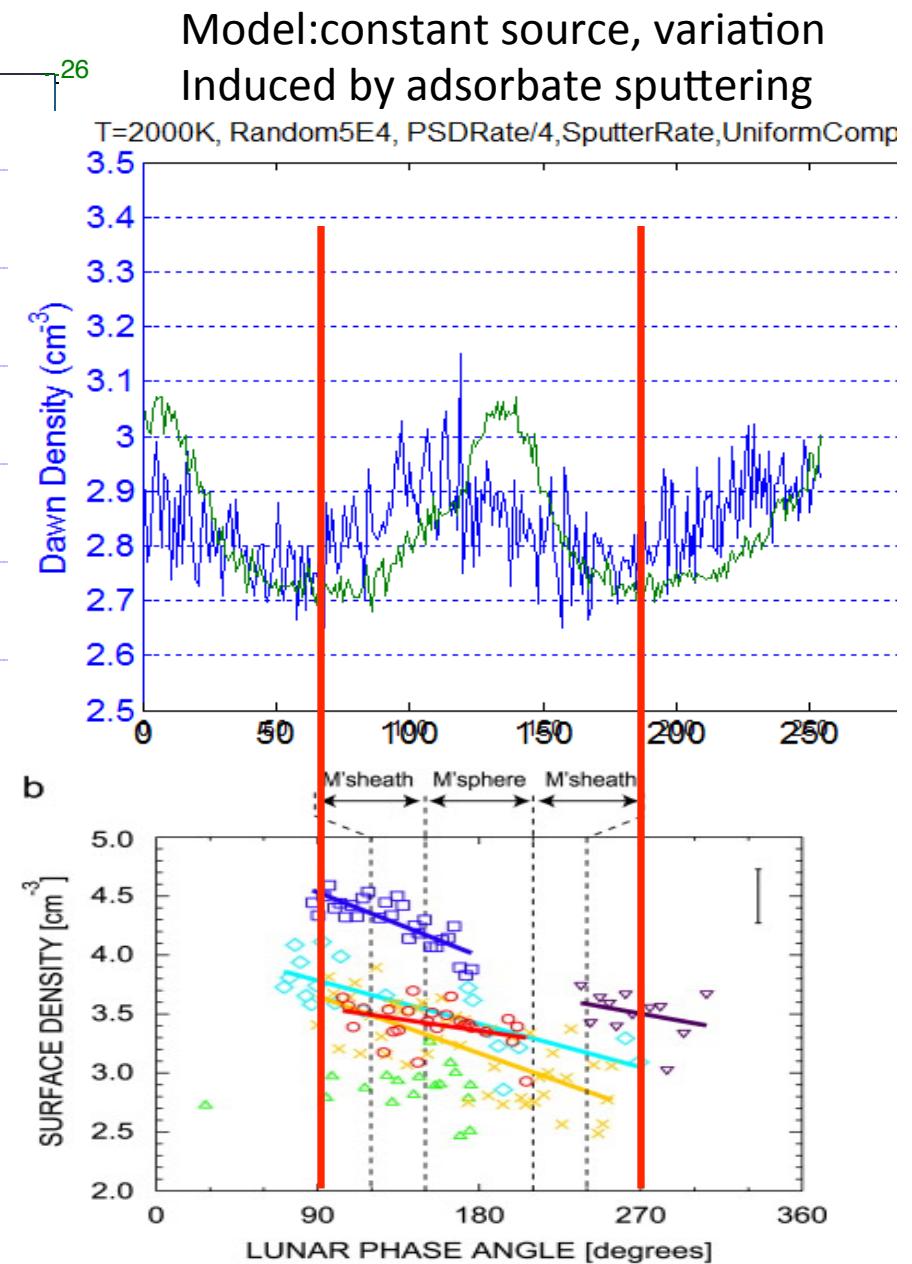
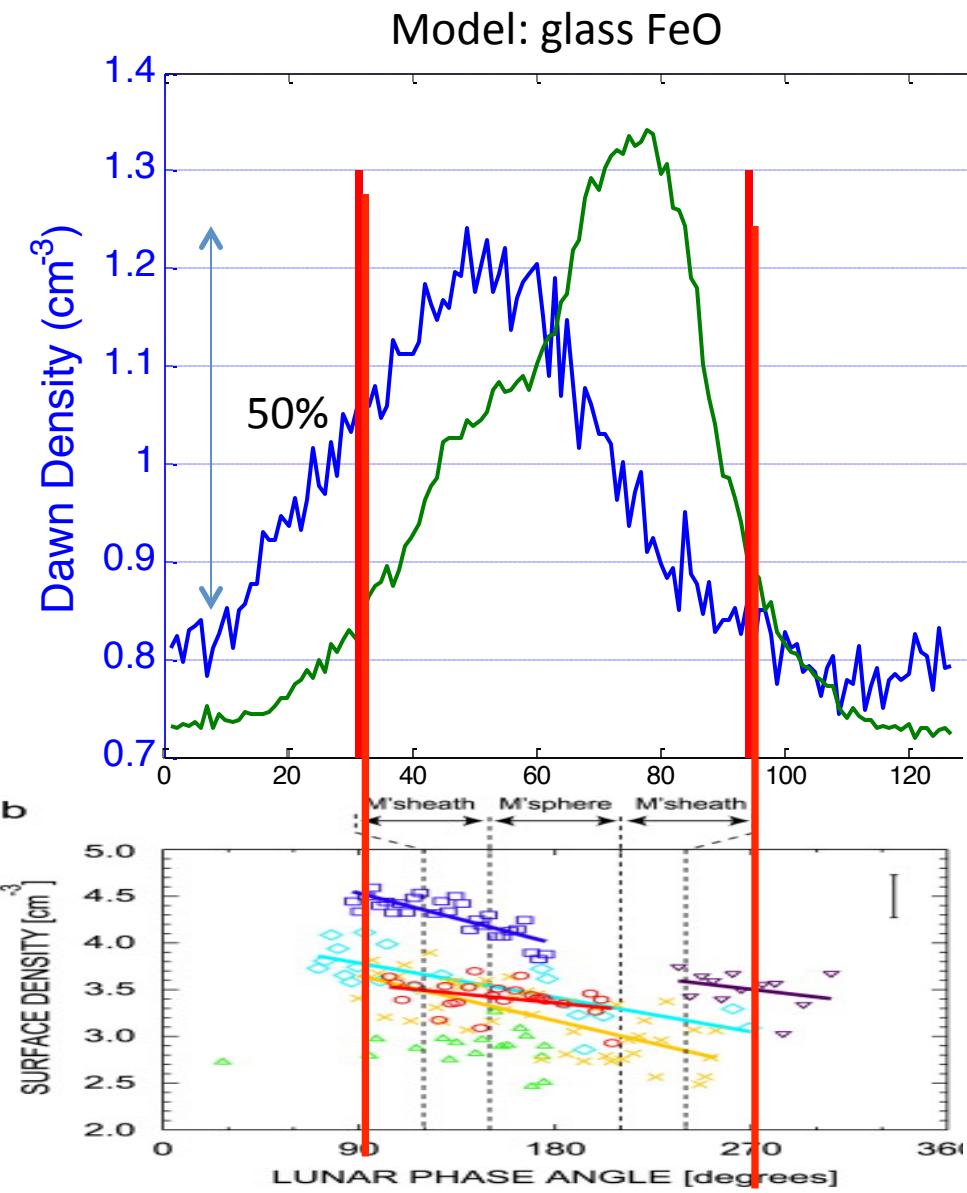
Na in/on pyrex glass (Telles et al., 2010)

# Summary of findings

- Unable to reproduce the variation in one month seen by UVS with any simple model.
  - "Simple" = using the same microphysical parameters for all soil types plus the assumption of constant source rate over a month.
- Two ways out:
  - 1. Microphysical parameters affecting soil residence times are higher on nearside; and/or
  - 2. Source rate is highest on nearside.
- Unless highlands are about 10 times less abundant in Na, we must infer highly variable (more than x2) PSD parameters across different lunar minerals and glasses

# Supplementary Material

# Bringing Kaguya and LADEE in agreement

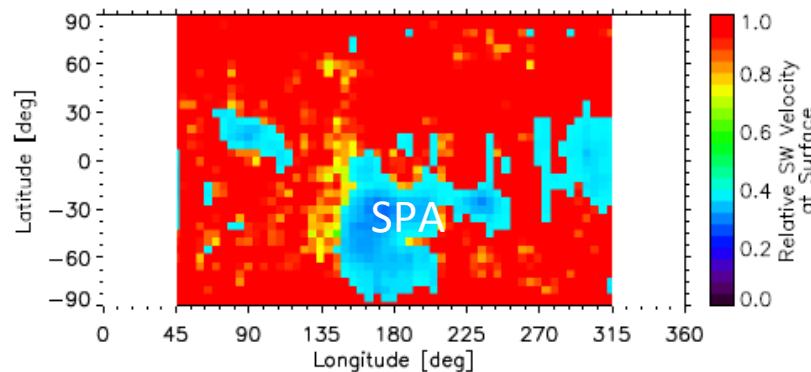


# The role of the solar wind

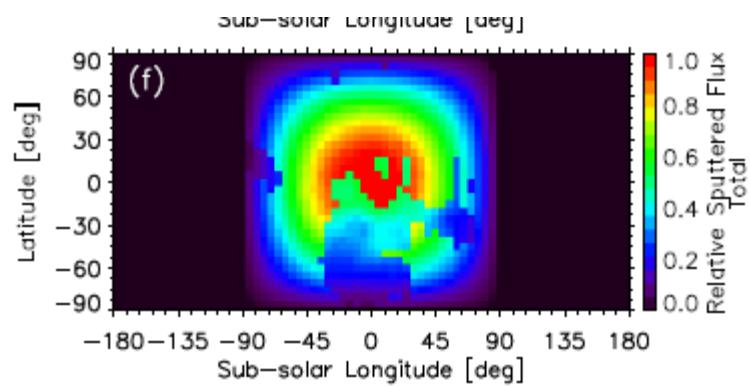
What is the role of the solar wind? Use large magnetic anomaly at SPA to find out!

Predictions of the effects of magnetic anomalies from Poppe et al. 2014

SW Proton Deceleration (data-driven model)

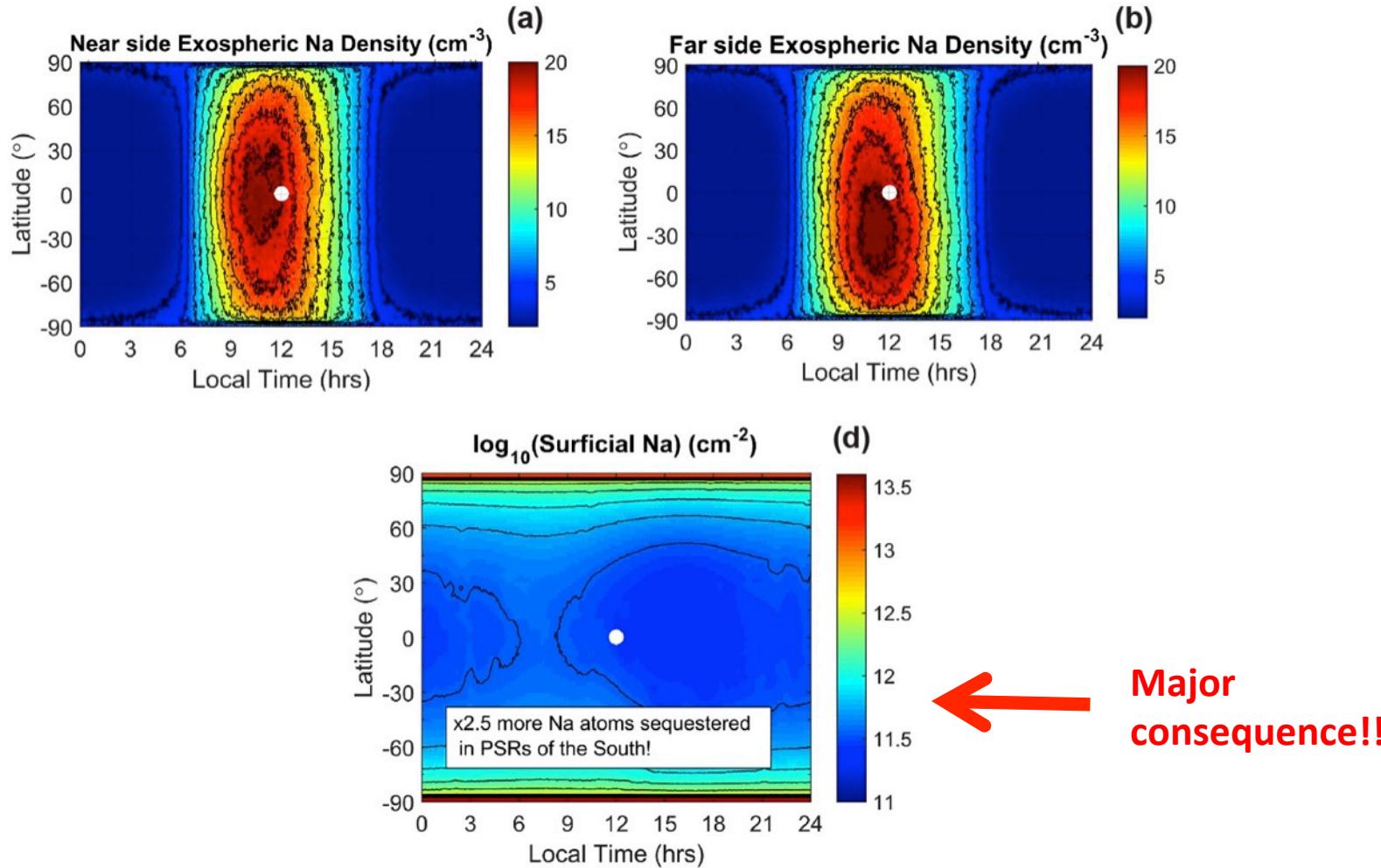


Sputtered flux w. 5% alphas (model)

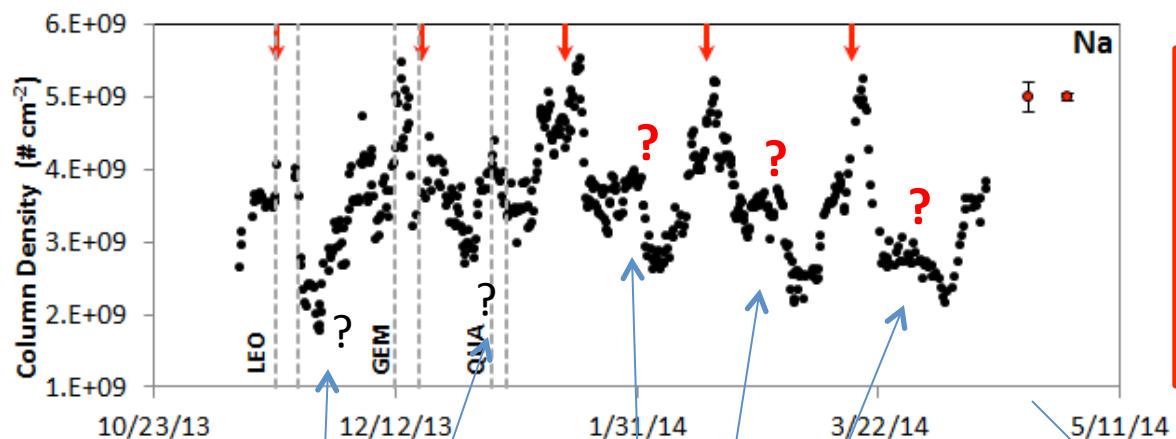


If solar wind is only/mainly removing alkalis, then Na& K atmosphere will be enhanced near SPA (since sputtering is reduced, hence particles accumulate in the soil there)

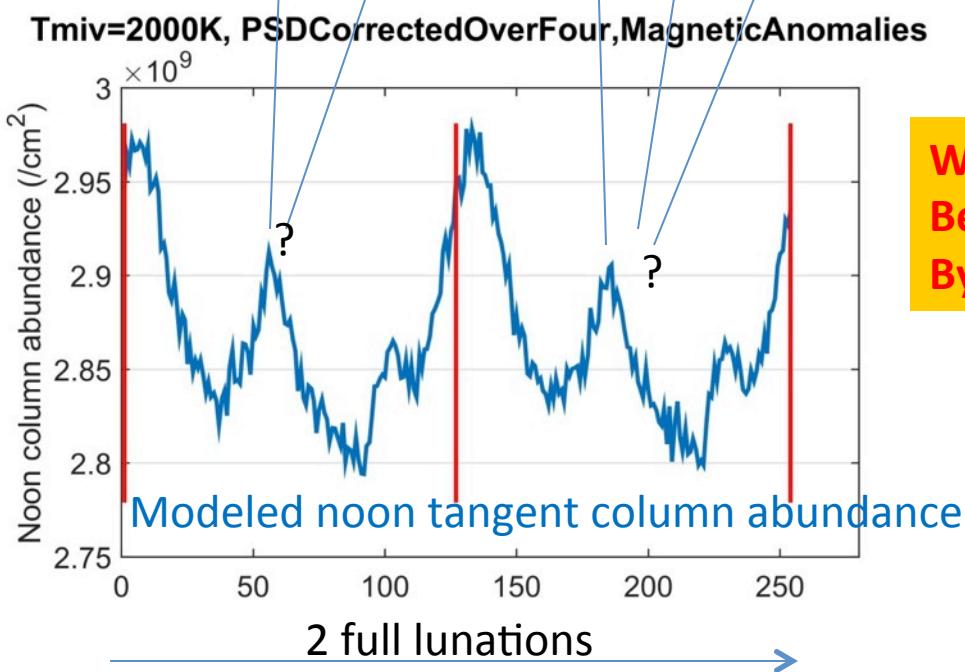
# Implications from sputtering of Na adsorbates



- If solar wind is the main sink for exospheric and surface particles, an exospheric peak at South near New Moon due to the shielding provided by the cluster of magnetic anomalies near South Pole-Aitken Basin



Evidence for effect  
of magnetic  
anomalies in LADEE  
UVS data?



We will never know (for sure)  
Because the LADEE “bump” is perturbed  
By major stream injections (GEM, QUA)